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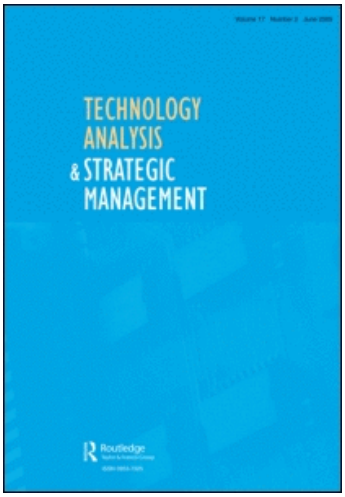

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Knowledge exchange behaviours of science park firms: the innovation hub case

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Knowledge exchange behaviours of science park firms: the innovation hub case

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This paper regards the knowledge flows between firms located on a science park as a type of network behaviour and answers three research questions: (1) What are the knowledge exchange behaviours of on-park firms? (2) Can we distinguish different types of behaviour among these firms?, and if so, (3) What are differences between these groups? We take a relational approach in which actor and relationship features are studied in a sample of firms located at the Innovation Hub (South Africa). Results show that there are two groups of firms: on-park firms that network with other on-park firms (Group 1) and those that do not (Group 0). Compared with Group 0, Group 1 has more informal ties with off-park firms; is able to gain more useful knowledge from private knowledge sources; and has more access to unintended knowledge that flows in the park. However, the innovative performance of the groups does not differ.

Keywords: science parks; knowledge exchange; networks; innovative performances; the innovation hub

1. Introduction

The majority of science park studies states that an important goal of science parks is to meet governments' requests for greater exchange of knowledge and ideas between on-park firms in general, and between these firms and higher educational institutions such as universities in particular to transform ideas into innovations. It is this kind of innovation that governments believe to be the key to economic development and growth in the region and therefore use science parks as a catalyst or engine (Chan and Lau 2005). Firms located on science parks are assumed to profit from the transmission of (tacit) knowledge as a result of lower communication costs in a dense and knowledge rich environment. Besides the knowledge exchange among on-park firms, there also can be knowledge exchanges with off-park firms. This type of knowledge exchange causes spillover effects of science parks so that the government's goal of (regional) economic development is achieved. Like many other developing countries' governments that were keen to invest in new science parks in an attempt to enhance economic competitiveness, the Innovation Hub (TIH) in Pretoria, South Africa was one such project by the Gauteng Provincial Government. This initiative has as its primary goals to stimulate and manage the flow of knowledge and technology

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among universities, R&D institutions, companies and markets so that it becomes the leading knowledge-intensive business cluster in South Africa.

From the above discussion, 'knowledge flows' between various actors play an important role in science parks. Therefore, in order to examine science parks, one should take knowledge flows into account and ask: 'To what extent are these "knowledge flows" actually occuring in a science park?' Exchanging knowledge is regarded as a type of network behaviour and therefore to study different types of knowledge flows, one needs to look at the characteristics of inter-organisational relations as they serve as pipelines for these knowledge flows (Owen-Smith and Powell 2004). The aim of this study is to get insights into the knowledge exchange behaviour of firms in a science park and, in particular, firms located at TIH. Three research questions will be answered:

1) What are the knowledge exchange behaviours of on-park firms?
2) Do these behaviours distinguish groups among on-park firms?
3) If so, what are the differences between these groups?

By answering these questions, this paper adds to the field in a number of ways. First, many studies take the science park as their level of analysis. This study takes a firm level perspective and investigates the knowledge exchange behaviour of firms located on a science park with other on- and off-park firms. Applying such an approach highlights knowledge diffusion processes in bounded geographical space. Second, and related to the first contribution, this paper takes a relational approach in which characteristics of inter-organisational ties are thought to be of importance for the performance of organisations. Including tie characteristics in studies of science parks is relatively new. Third, while studying the performance of science parks or its firms many scholars use patents as a performance indicator. This paper applies a broader set of performance indicators in which not only inventions but also innovations (invention + market introduction) are taken into account. Fourth, recent science park studies tend to focus on parks in Asia (Taiwan, China, South Korea). This paper studies firms located on a science park in (South) Africa. To our knowledge, this is one of the first papers investigating the functioning and performance of science parks firms on this continent.

The remainder of this paper is structured as follows. By taking a relational approach, Section 2 gives a brief review of the literature on networking and discusses how characteristics of inter-organisational ego networks influence innovations. Section 3 describes the research methodology that is used and how the variables were measured. Section 4 describes the results of a survey of TIH resident companies (on-park firms) which the authors carried out in 2008, focusing on the characteristics of knowledge exchange relationships and the actors involved. The discussion in this section includes the possible group distinctions and differences in knowledge exchange behaviours and innovative performances between them. Section 5 provides some concluding remarks.

2. Theoretical framework

2.1. *Introduction*

In the introduction of this paper, it was stated that a relational perspective will be applied to study knowledge exchange behaviours of science park firms. But what is this relational approach? In this approach, organisations are viewed as embedded in external networks and consisting of networks of relations within teams, with employees, suppliers, buyers, institutional actors such as governments, regulatory bodies, social movements, professional associations, employers organisations

and trade organisations. The approach argues that relationships and their characteristics (e.g. the level of exchanges, trust or knowledge transfer) are relevant for understanding organisational behaviour and outcomes. The approach represents a move 'away from individualist, essentialist and atomistic explanations toward more relational, contextual and systematic understanding' (Borgatti and Foster 2003, 991). The forging of productive relations with a highly differentiated set of partners is one of the core activities of organisational decision makers. The sets of relations legitimise organisational actions and strengthen organisations' embeddedness in an organisational field and in society. Relations also co-determine survival chances of organisations because the relations enable access to complementary resources, create potential for avoiding risks, they show reputation and status, and hence allow for the assets and resources needed to develop adaptive repertoires and innovative strategies to cope with competitive and institutional pressures.

When studying inter-organisational relations and networks, a basic building block of any network is an inter-organisational relationship, which is also known as a dyad. Per definition, each dyad consists of two actors and a tie. Consequently, studying knowledge exchange behaviours of science park firms implies that one has to focus on so-called tie and actor characteristics.

In the next two sections, the focus is on a number of tie characteristics related to intended and unintended knowledge exchanges, which are, according to the literature, of importance to innovation. In a subsequent section, a number of actor characteristics are discussed, such as firm age, firm size, years located on a science park and its absorptive capacity as they also contribute to firm's innovative performance and network behaviours.

2.2. *Tie characteristics*

Relational characteristics include three categories: tie type (inter-organisational knowledge flows), the number of direct ties (degree centrality) and tie strength (trust, proximities, frequency and usefulness of the knowledge flowing in the tie).

Intended and unintended knowledge flows

The literature distinguishes between two types of inter-organisational knowledge flows: intended and unintended knowledge flows (Fallah and Ibrahim 2004; Oerlemans and Meeus 2005). *Intended* knowledge flow refers to flows between two actors who intentionally interact with the aim to exchange their knowledge resources. Researchers relate *unintended* knowledge flows to the knowledge spillover literature (Howells 2002; Oerlemans and Meeus 2005). They define unintended knowledge flows as the transmission to other actors on an involuntary and unintended basis, or in other words, unintentional transmission of knowledge to others beyond the intended boundary. This type of knowledge can be acquired without the acknowledgement of the sending firms and often zero or low costs are involved. That this is a relevant issue in the South African context is shown in several studies. Sawers, Pretorius and Oerlemans (2008) stated that there are unintentional knowledge flows from small and medium-sized enterprises (SMEs) to their larger partners in South Africa. In the study 'Industrial innovation in South Africa, 1998–2000' by Oerlemans et al. (2004), it is shown that many South African innovative firms benefit from this type of knowledge flow, which results in an imitation type of innovative behaviour. In other knowledge spillover studies, researchers also attribute innovative performance to knowledge spillovers (Fallah and Ibrahim 2004; Oerlemans and Meeus 2005). In this study, two dimensions of unintended knowledge flow are distinguished: the flow between on-park firms and between on-park firms and its off-park actors.

Number of ties

Through networks, firms are able to access knowledge externally and apply this acquired external knowledge to develop their own innovations. When firms interact formally (by explicit agreement) or informally (on a social basis), knowledge sharing often occurs. Evidence from the literature illustrates that 'those firms which do not co-operate and which do not formally or informally exchange knowledge, limit their knowledge base over the long term and ultimately reduce their ability to enter into exchange relationships' (Pittaway et al. 2004, 145). Network position, such as centrality, is an important aspect of a network structure because it conditions the degree to which an actor can have access to resources throughout the network; the more a firm is central in its network, the more it can compare knowledge across multiple knowledge sources and discover new knowledge. Furthermore, firms with a more central position are less likely to miss any vital knowledge and are able to combine knowledge in novel ways to generate innovations (Bell 2005). In this paper, centrality is examined using degree or local centrality that is measured by determining the number of direct relationships a so-called ego firm has with other actors. Various studies have shown that centrality is positively associated with innovation and enhances firm performance (Ahuja 2000; Zaheer and Bell 2005).

Trust

Studies have identified trust in relationships as an important relational asset that promotes the willingness to exchange knowledge (Abrams et al. 2003). Trust is often desired by knowledge-intensive and information-based firms who require sharing of sensitive information (Lane and Bachmann 1998). Zaheer, McEvily and Perrone (1998, 143) conceptualised trust as an 'expectation rather than a conviction that reflects an uncertain anticipation of the referent's future behaviour'. They defined trust as the *expectation* that an actor: (1) can be relied on to fulfil obligations; (2) will behave in a predictable manner; and (3) will act and negotiate fairly when the possibility for opportunism is present (*ibid.*). They distinguished two types of trust: inter-organisational and interpersonal. Both dimensions of trust form the foundation for effective interactions among actors and this can be observed by investigating trust deeper into its two forms.

Based on past interactions, when two actors are emotionally involved with each other and eventually trust is built between them, the more time and effort to transfer knowledge they are willing to put forth on behalf of each other. This form of trust is called 'intentional trust' (Lazaric and Lorenz 1998) because it refers to the belief that partners intend to uphold the commitments they made. Another form of trust is 'competence-based trust', which refers to the belief partners have the capability to meet their commitment. In this study, trust refers to the belief that a partner is capable (competence-based of trust) to provide the knowledge a firm needs for innovations as well as the belief that a partner is willing to share such knowledge for the benefit of the other (intention-based trust). Therefore, higher trust levels are assumed to be conducive for exchanging knowledge and thus reduce knowledge protection (Norman 2002).

Types of proximity

Gertler (1995, 1) found that 'recent work on innovation and technology implementation suggests the importance of closeness between collaborating parties for the successful development and adoption of new technologies'. Two actors are considered as close because they are alike (Torre and Rallet 2005) and this closeness between actors can be labelled as 'proximity', which refers to 'being close to something measured on a certain dimension' (Knoben and Oerlemans 2006, 71). There are various dimensions of proximity and they often overlap in their meanings and

dimensions. For this study, the classification of proximity dimensions developed by Knoben and Oerlemans (2006) is used. They discern geographical, technological and organisational proximity.

In the study of innovation and knowledge transfer, there is an emphasis on the literature of geographical proximity. It is often defined as geographical distance expressed as a specified radius to a partner (Orlando 2000) or travel times/perception of these distance (Boschma 2005). A short distance between two actors facilitates knowledge sharing and the transfer of tacit knowledge in particular. Tacit knowledge transfer is enhanced through face-to-face contacts and these contacts are the richest and most multidimensional available to humans (Desrochers 2001). Therefore, the spatial dimension becomes essential to enhance the exchange of tacit knowledge for innovative activities and one could argue that the high level of proximity science parks offer is conducive to the exchange of knowledge.

Furthermore, Desrochers (2001, 29) mentioned that 'geographical concentration of *related firms* balances cooperative and competitive forms of economic activity, leading to greater innovation and flexibility'. The term 'related' points at similarity of technological backgrounds and knowledge between these firms. Technological proximity refers to the similarities between actors' technological knowledge, in other words, how related is the knowledge exchanged between them. The transfer of unrelated knowledge can cause difficulties because the firm that receives the knowledge is not capable of identifying, assimilating and exploiting the knowledge coming from external sources for its own innovative activities (Sapienza, Parhankangasand, and Autio 2004). On the other hand, the transfer of unrelated knowledge contributes to efficient communication because knowledge can only be easily exchanged if both actors share similar language, codes and symbols (Grant 1996). Moreover, closely related external knowledge is also likely to be more compatible than unrelated knowledge so that the receiving firm is able to *absorb* such knowledge from the sender for its own use (relative absorptive capacity, see Lane and Lubatkin 1988).

The third dimension is 'organisational proximity'. It is defined as 'the set of routines – explicit or implicit – which allows coordination without having to define beforehand how to do so. The set of routines incorporates organizational structure, organizational culture, performance measurements systems, language and so on' (Knoben and Oerlemans 2006, 80). Lane and Lubatkin (1988) stated that similarity of both firms' organisational structures and policies contributes towards firms' ability to interactively learn from each other. This interactive learning does not only occur at the individual level but also at the organisational level where its structure and routines represents the codification of the organisation's historic pattern of roles and organisation's communication processes. Collaborating firms that have low organisational proximities have different sets of routines and thus instead of creating innovations together, they create problems because of these routines; for example, they cannot communicate well as a result of their different communication processes. For a worst result of such difference, an unsuccessful collaboration leads to no innovative outputs.

Frequency and knowledge usefulness

Soo and Devinney (2004) found a positive relationship between quality of knowledge transferred and innovative performance. The quality of knowledge transferred comprises two factors: usefulness of the knowledge that a firm receives and how frequent it receives the knowledge. The context of the knowledge that a firm receives directly, influences the success of the innovative outcomes if the firm can actually use such knowledge. The knowledge can be new to the receiving firm, but if it cannot be used and contribute to the firm's development of new innovation, then such knowledge has low knowledge quality to the firm. This is in line with Brachos et al. (2007), who pointed out that knowledge transfer actually occurs when received knowledge is used to lead

to something new (i.e. ideas, products, deeper knowledge, etc). Furthermore, they suggested that perceived usefulness of knowledge is an adequate proxy of knowledge transfer effectiveness.

The frequency of knowledge exchange is the quality of the knowledge exchange because more frequent communication can lead to more effective communication (Reagans and McEvily 2003). With repeated interaction the receiving firm can better understand the knowledge that it receives and increase the chances that the knowledge is useful for the firm's innovation. Audretsch and Feldman (2004) state that the marginal cost of transmitting knowledge, especially tacit knowledge, is lowest with frequent interactions, observations, and communications. Frequent interactions also enhance both parties mutual trust because relationships mature with interaction frequency (Atuahene-Gima and Li 2002). Studies have shown that mutual trust affects the grade of tacit knowledge utilisation (Koskinen, Pihlanto, and Vanharanta 2003).

2.3. *Actor characteristics*

Actor characteristics contribute to the analysis of network behaviours and innovative performances of firms. These characteristics include the diversity of external actors, firm age and size, duration of location in the science park and a firm's absorptive capacity.

Diversity of external actors

Many innovators derive their ideas from a diverse set of actors because these provide diverse ideas which is a source of novelty triggering new ideas and creativity in the knowledge acquiring firm. Actors who interact with partners from diverse communities of practice will be able to convey more complex ideas than those individuals who are limited to interactions within a single body of knowledge (Reagans 2003).

The process of knowledge building often requires dissimilar, complementary bodies of knowledge from diverse actors (Staber 2001) who interact with each other to share diverse knowledge and take advantage of their 'built in' knowledge diversity further towards successful projects (Ratcheva 2009) and to achieve a complex synthesis of highly specialised state-of-the-art technologies and knowledge domains for product innovations (Dougherty 1992). A recent study also showed that knowledge diversity is an important source of productivity at firm level so that the firm is able to cope with technological turbulence that exists in the rise of the knowledge economy (Nesta 2008). Diversity is defined here as the use of 'multiple sources of knowledge' such as competitors, customers, suppliers, higher education institute (HEI), etc.

Firm age and size

Prior studies identified a significant positive relationship between firm size and innovativeness and a significant negative relationship between firm age and innovativeness (Bell 2005). Firm size in this study is identified by the number of full-time employees, including chief executive officers (CEOs) and directors employed by a firm and firm age is the number of years that past after a firm's founding. Small and young firms often face significant risk and uncertainty owing to a lack of information and knowledge (Bürgel et al. 2001). For a firm to be innovative and competitive, accumulation of knowledge plays an important role (Malmberg, Sölvell and Zander 1996) and this needs time and people to acquire knowledge. In particular, firm size determines the level of networking because 'people' are at the core of tacit knowledge exchange to take place (Erkuş-Öztürk 2009). Science parks are designed to encourage the formation and growth of knowledge-based businesses and therefore mainly consist of young and small sized new-technology based firms (NTBFs).

Years of location in science parks

Science parks (SP) are believed to have many value added contributions towards firms (Fukugawa 2006), especially focusing on providing the opportunities (close geographical proximity) and support (from the science park management) to their on-park firms to establishing knowledge linkages and allowing on-park firms to engage in joint research. Firms that have longer duration in a science park are considered to receive more of such benefits than those who are late comers in the park.

Absorptive capacity

Following Cohen and Levinthal's seminal study (1990), firm's fundamental learning processes (its ability to identify, assimilate and exploit knowledge from the environment) is labelled absorptive capacity. Zahra and George (2002) proposed additional definitions that separate Cohen and Levinthal's definition of absorptive capacity into two main dimensions: potential absorptive capacity (the capability to acquire and assimilate knowledge) and realised absorptive capacity (the exploitation or use of the knowledge that has been absorbed). Many empirical studies have shown that there is a positive relationship between absorptive capacity and innovation. Pennings and Harianto's study (1992) showed that prior accumulated experience in a certain technological area increased the likelihood of innovation adoption. Nelson and Wolff (1997) and Becker and Peters (2000) argue that firms need higher absorptive capacities for scientific knowledge than for other types of knowledge. More recent literature also explores the positive relationship between absorptive capacity and innovations (Fosfuri and Tribó 2008), and it's relevance for absorbing external knowledge.

2.4. *Innovative performance*

Science parks are closely associated with innovation. In Castells and Hall's (1994) list of motivations for the establishment of technology parks, 'creation of synergies' was described as the generation of new and valuable information through human intervention to the extent that an 'innovative milieu', which generates constant innovation, is created and sustained. Besides the study of on-park firms' knowledge exchange behaviours and also since a science park is the seedbed for innovation, this paper also investigates the innovative performances of the on-park firms. Innovative performance is based on the definition from Ernst (2001): achievement in the trajectory from conception of an idea up to the introduction of an invention into the market.

3. Research methodology and measurements

3.1. *Research methodology*

In this paper, the focus is on the knowledge exchange behaviours of firms located on a science park. Therefore, the unit of analysis is firms located on TIH in Pretoria, South Africa. The sectoral distribution of current on-site firms (total = 47) is as follows: Bioscience: 5; Electronics: 2; Engineerings: 6; Information, communication and technology (ICT): 28; Smart manufacturing: 1; and Professional services: 5.

This research applies a quantitative research methodology. A questionnaire was distributed among firms located in TIH and the CEOs or directors (units of observation) of these firms were asked to answer questions based on the characteristics of their firms' knowledge exchange behaviours with other on-park firms as well as with off-park firms/organisations (firms not

Table 1. Descriptions of variables.

Variables	Item(s)
Direct ties	Formal interorganisational network ties: with how many on-park and off-park organisations does the on-park firm have formal/contractual agreements? Informal interorganisational network ties: with how many on-park and off-park organisations does the on-park firm have interactions on a non-contractual basis (i.e. informal, social basis)? Social network ties: with how many persons of on-park and off-park does the manager of the on-park firm have social interactions?
Trust	*Interorganisational trust*: Indicate level of agreement with the following statements: In general, the organisations with which my firm exchanges knowledge: (1) keep promises they make to our firm; (2) are always honest with us; (3) provide information that we can believe; (4) are genuinely concerned that our business succeeds; (5) consider our welfare as well as their own when making important decisions; (6) keep our best interests in mind; (7) are trustworthy; (8) it is not necessary to be cautious in dealing with them. *Interpersonal trust*: Indicate level of agreement with the following statements. In general, the persons with which my firm exchanges knowledge: (1) have always been impartial in negotiations with us; (2) can always be counted on to act as we expect; (3) are trustworthy; (4) consider our interests even when it is costly to do so; (5) if their performance was below our expectations, we would feel a sense of betrayal. (7 points Likert scale for all above items: 1 = completely disagree, 3 = neither agree nor disagree, 7 = completely agree)
Geographical proximity	Geographical distances with respect to off-park firms: Where are the most important partners situated: (1) same town/city, (2) different city but same province, (3) other province or (4) abroad?
Technological proximity	Technology relatedness: To what extent is the knowledge your firm receives from the most partners/actors related to your firm's own knowledge? (7 points Likert scale: 1 = not related to 7 = completely related)
Organisational proximity	Our firm has contacts with the same third parties as our partners have Our partners have the same organisational routines and values as our firm Our partners have the same organisational structure as our firm (5 points Likert scale: 1 = completely disagree, 3 = neither agree nor disagree, 5 = completely agree)
Quality of knowledge transferred	*Usefulness of knowledge*: How useful is the knowledge your firm receives from the most important partners with regard to your firm's innovations? (5 point Likert scale: 1 = not useful to 5 = completely useful) *Frequency*: How often does your firm access knowledge from its most important partners? (5-point Likert scale: never, rarely, sometimes, regularly or always)
Diversity of actors	Respondents were asked indicate which knowledge sources were used: (1) competitors; (2) buyers;(3) suppliers; (4) innovation centres; (5) public research labs; (6) universities; (7) consultants; and (8) sector institutes
Knowledge spillover (unintended knowledge flows)	How often does your firm use the following sources from other organisations/actors to acquire knowledge for your firm's innovations?: (1) employing key scientists and engineers (including poaching key staff); (2) acquiring key information at conferences and workshops; (3) reverse engineering of technological knowledge embedded in products developed/produced by other firms/organisations; (4) accessing patent information filed by other firms/organisations; (5) knowledge embedded in organisational processes or routines of other firms/organisations; (6) publications in technical and scientific papers by other firms/organisations. (5 point Likert scale: never, rarely, sometimes, regularly or always)

(*Continued*)

Table 1. Continued.

Variables	Item(s)
Firm age	Number of years a firm exists
Firm size	Total number of employees including the CEOs and directors in 2005 and 2007
Years in SP	Total number of years that the firm is located in the science park (SP)
Absorptive capacity	Indicate level of agreement with the following statements: (1) most of our staff is highly skilled and qualified; (2) we invest a great deal in training; (3) we innovate by improving competitors' products and processes; (4) most of the time we are ahead of our competitors in developing and launching new products; (5) we have the capacity to adapt others' technologies; (6) we innovate as the result of R&D carried out within our own firm; (7) we have considerable resources and own knowledge resources for technological development; (8) we are able introduce into the market innovations which are completely novel on a worldwide scale. (5 points Likert scale: 1 = strongly disagree, 3 = neither agree nor disagree, 5 = strongly agree)
Firm's innovative performance	Five indicators of innovative performance were used: (1) number of patents; (2) number of new products/services that were developed but did not yet introduced to the market; (3) percentage of sales of products/services that were technologically improved and technologically new in percentage; (4) percentage of sales of product/services that were not only technologically improved or new but also technologically new or improved in the market (the competitors had not already introduced such product/services); (5) relative innovative performance. For this last item, the following question was asked. To what extent did your firm's product and/or service innovations result in?: (a) reduction of development and maintenance costs; (b) quality improvement of products and/or services; (c) increase in production capacity; (d) improvement in delivery times; (e) increase in sales; (f) increase in profits. (5 points Likert scale: 1 = very little, 3 = not little/not much, 5 = very much)
Total sales growth	Relative growth of sales in the period 2005–2007
Employee growth	Relative growth of employee volume in the period 2005–2007
Labour productivity	Sales volume per employee in 2007
Labour productivity growth	Relative growth of labour productivity in the period 2005–2007

located in TIH). Questionnaires were distributed personally or via emails to all NTBFs and 33 were returned. Twenty-five questionnaires were valid (response rate = 52%), within which 17 were from ICT, 4 from Engineering, 2 from Professional Services and 1 from Electronics. Eight responses were invalid owing to the firm characteristics not meeting our criteria for inclusion (too large and/or non-technological firms). The collected data were analysed by applying independent T-tests.

3.2. *Measurements*

This reseach studies the knowledge exchange behaviours of on-park firms at the ego-network level (an ego-network is a focal firm (the ego) with its direct ties, the alters) rather than at the whole network level (which requires data on the entire set of present and absent linkages among a set of actors).

Table 1 illustrates the items that are used in the questionnaire to measure the variables proposed in the research framework. Table 2 shows the literature that was sourced to construct our

Table 2. Measurements, their sources and reliability statistics.

Variables	Source and Cronbach's α of items in this source if provided	Measurement and Cronbach's α of items in this research if applicable
Direct ties	Otte and Rousseau (2002)	*Formal interorganisational network ties*: count of total number of ties *Informal interorganisational network ties*: count of total number of ties *Social network ties*: count of total number of ties
Trust	*Inter-organisational trust*: Lippert (2007) ($\alpha = 0.94$)	*Inter-organisational trust*: average sum score of all eight items using the 7-point Likert scale ($\alpha = 0.938$)
	Interpersonal trust: Zaheer, McEvily and Perrone (1998) ($\alpha = 0.88$)	*Interpersonal trust*: average sum score of all 5 items using the 7-point Likert scale ($\alpha = 0.834$)
Geographical proximity	Schreurs (2007)	Coding: 1 = same town/city, 2 = different city but same province, 3 = other province, 4 = abroad
Technological proximity	Cassiman et al. (2005)	1 item: 5-point Likert scale
Organisational proximity	Knoben and Oerlemans (2006)	Average sum score of all three items using the 5-point Likert scale (On-park: $\alpha = 0.566$; Off-park: $\alpha = 0.853$)
Quality of Knowledge transferred	Soo and Devinney (2004)	1 item: Usefulness of knowledge, 5-point Likert scale 1 item: Frequency, 5-point Likert scale
Diversity of actors	Oerlemans et al. (2004)	Count of total number of different knowledge sources.
Knowledge spillover (Unintended knowledge flows)	Howells (2002)	Average sum score of all six items using the 5-point Likert scale (On-park: $\alpha = 0.566$; Off-park: $\alpha = 0.853$)
Firm age	Source: not applicable	2008 (the year when this research was conducted) minus the founding year of the firm
Firm size	Source: not applicable	Count of the total number of employees in year 2005 and 2007
Years in SP	Source: not applicable	2008 (the year when this research was conducted) minus the year when the firm is located in the science park
Absorptive capacity	Nietoa and Quevedo (2005)	Average sum score of all eight items using the 5-point Likert scale ($\alpha = 0.771$)
Firm's innovative performance	Cassiman et al. (2005) *Relative innovative performance*: Oerlemans and Meeus (2005)	(1) Total number of patents in year 2005 and 2007 (2) Total number of new products/services that were developed but did not yet introduced to the market in year 2005 and 2007 (3) Innovative sales: Percentages of sales of products/services that were technologically improved and technologically new (4) Percentage of sales of product/services that were not only technologically improved or new but also technologically new or improved in the market

(*Continued*)

Table 2. Continued.

Variables	Source and Cronbach's α of items in this source if provided	Measurement and Cronbach's α of items in this research if applicable
		(5) Relative innovative performance: average sum score of all six items using the 5-point Likert scale ($\alpha = 0.656$)
Total sales growth	Source: not applicable	[(Total Sales 2007 – Total Sales 2005)/Total Sales 2005] $\times$ 100
Employee growth	Source: not applicable	[(Number of employees 2007 – Number of employees 2005)/Number of employees 2005] $\times$ 100
Labour productivity	Source: not applicable	Total Sales 2007/Number of employees 2007
Labour productivity growth	Source: not applicable	[(Labour productivity 2007 – Labour productivity 2005)/Labour productivity 2005] $\times$ 100

measurements, as well as the reliability statistics (Cronbach's α) of the scales used. Table 2 shows that there are several variables measured by more than one item. Examples are trust, organisational proximity and relative innovative performance. In these cases, factor analysis was conducted to explore the underlying dimensions of these specific variables. It turns out that there is one factor each for both interorganisational trust and interpersonal trust.

A reliability test is then done on these variables to deterimine how well the items measure a single, unidimensional latent construct. This procedure is performed for all relevant variables and the results are shown in the last column of Table 2. Most varibales have Cronbach's α's $\geq$0.6, which indicates reliable scales. Note that the Cronbach's α for off-park organisational proximity is 0.442. This means that for off-park organisational proximity separate items will be used independently to measure this variable.

4. Empirical results

In this section the first two research questions: '(1) What are the knowledge exchange behaviours of on-park firms?' and '(2) Do these behaviours distinguish groups among on-park firms?' are answered by applying descriptive statistics on tie and actor characteristics.

4.1. *Descriptive statistics: tie characteristics*

As mentioned in the theoretical section, studying knowledge exchange behaviours of science park firms implies that one has to focus on tie and actor characteristics. In Table 3, descriptive statistics are presented on ties of on-park firms with both other on- and off-park firms.

The mean of the number of direct ties of on-park firms with off-park firms is higher than the means of ties with on-park firms in all (formal, informal and social) direct ties categories. On-park firms not only have more ties with off-park firms, they also interact more frequently with these off-park firms. These observations indicate that there is quite a number of respondents that have few and infrequent on-park interactions.

Table 3. Mean and standard deviation (SD) of variables ($N = 25$).

Relational characteristics					
		With On-park firms/organisations		With off-park firms/organisations	
	Variables	Mean	SD	Mean	SD
Direct ties	Number of formal ties	0.48	1.005	19.32	40.197
	Number of informal ties	1.52	1.896	12.08	11.228
	Number of social ties	4.40	6.212	79.84	263.693
	Total number of ties	2	2.29	31.4	40.57
Trust	Interorganisatioal	Mean = 4.9150, SD = 1.17245			
	Interpersonal	Mean = 4.4240, SD = 1.15372 (trust levels in general, no on-park or off-park differentiation)			
Geographical proximity	With competitors			1.04	0.338
	With buyers	Mean = 1, SD = 0		1.56	1.158
	With suppliers			1.72	1.487
	With innovation centre	On-park firms are all situated in close geographical proximity		0.44	0.917
	With public research labs	(1 = same city)		0.20	0.5
	With university			0.72	1.275
	With consultant			0.96	1.020
	With sector institutes			0.36	0.757
Technological proximity	With competitors	0.96	2.031	2.68	2.911
	With buyers	0.32	1.145	3.88	2.522
	With suppliers	1.56	2.181	3.44	2.694
	With innovation centre	0.72	1.792	1	1.979
	With public research labs	0.16	0.624	0.84	2.035
	With university	0.72	1.990	1.44	2.417
	With consultant	0.48	1.388	2.92	2.857
	With sector institutes	0	0	1.28	2.622
Organisational proximity	Same third parties	1.60	1.756	2.88	1.364
	Same routines and values	1.64	1.753	3.32	1.069
	Same structure	1.76	1.877	2.52	1.122
Frequency	With competitors	0.36	0.860	0.88	1.054
	With buyers	0.24	0.879	2.64	1.319
	With suppliers	1.04	1.338	2.12	1.453
	With innovation centre	0.44	0.961	0.60	1.155

(*Continued*)

Table 3. Continued.

		Relational characteristics			
		With On-park firms/organisations		With off-park firms/organisations	
	Variables	Mean	SD	Mean	SD
	With public research labs	0.12	0.440	0.32	0.900
	With university	0.2	0.577	0.56	1.121
	With consultant	0.32	0.748	1.68	1.464
	With sector institutes	0	0	0.56	1.261
Usefulness of knowledge	With competitors	0.76	1.640	1.64	1.890
	With buyers	0.40	1.384	3.60	1.848
	With suppliers	1.76	2.107	2.84	1.993
	With innovation centre	0.72	1.542	0.88	1.666
	With public research labs	0.24	1.012	0.60	1.443
	With university	0.52	1.447	1.00	1.732
	With consultant	0.60	1.500	2.36	2.139
	With sector institutes	0	0	0.88	1.833
Diversity of actors		1.32	1.676	3.56	1.583
Unintended knowledge flows		0.6872	0.39179	1.5733	0.77740

In general, on-park firms have more trust on an organisational level than on a personal level. Since trust enhances commitment to a relationship and trust at the organisational level is a stronger predictor of commitment than at the personal level (Ganesan and Hess 1997), the on-park firms are also slightly more committed to relationships at the organisational level rather than at the personal level.

As far as geographical proximity is concerned, most off-park partners of on-park firms are located geographically close. The relationships with buyers and suppliers seem to be the exception, but even in these cases partners seem to be relatively spatially close.

The variable technological proximity indicates how related the externally acquired technological knowledge is to the knowledge base of the focal firm. Given the low averages in Table 3, it can be concluded that on-park firms acquire external knowledge that is largely unrelated to their own knowledge. This finding shows that inter-organisational knowledge exchange relations often are based on the combination of complementary knowledge bases. It is also found that respondents get more related technological knowledge from off-park firms than from other on-park firms. This implies that in general, the technological proximity within the Hub is low. In other words, the technological knowledge backgrounds among the on-park firms differ quite a bit as compared to off-park firms.

This is also the case for organisational proximity: most partners of on-park firms seem to be organisational distant. Moreover, on-park firms feel more organisationally close to off-park firms on all dimensions of organisational proximity (relational, cultural and structural).

The relatively high levels of organisational and technological distance among the Hub firms may be the explanation for the relatively lower levels of perceived usefulness of knowledge acquired from other on-park firms in the Hub as compared to the usefulness of the knowledge acquired from off-park firms. In terms of diversity of actors, the on-park firms interact more with off-park actors from different categories and the diversity in the Hub is quite limited. This implies that there are less diverse communities of practice in the park.

4.2. *Descriptive statistics: characteristics of on-park firms*

Table 4 shows the descriptive statistics of the actor (on-park firms) characteristics. At the time of writing the average firm age and size are 5.28 years and 15.64 employees respectively and show that the on-park firm are small firms. This corresponds with most observations from science park researchers in the past (Löfsten and Lindelöf 2002). The Innovation Hub was opened officially in April 2005, so the park age since official opening is 4 years and on average the on-park companies have located in the Hub for almost 3 years. This implies that most of the current on-park firms have located in the Hub during the first year of official opening. On-park firms have an average score of 3.74 on a scale of 5 on absorptive capacity. This high absorptive capacity level accounts may be for the higher percentages of innovative sales (percentage of new and improved innovations to the market almost 46%; percentage of sales of improved innovations 44.6%; and percentage of sales of new innovations 35.4%). The average score for other results of innovations is also high on a scale of 5 (3.77).

4.3. *Comparing knowledge exchange behaviours of on-park firms*

4.3.1. *Introduction*

By taking a closer look at our data, two knowledge exchange groups of on-park firms can be distinguished: on-park firms that exchange knowledge with other on-park firms and those that

Table 4. Mean and standard deviation (SD) of variables ($N = 25$).

	Firm characteristics	
Variables	Mean	SD
Firm age	5.28	3.803
Firm size	15.64	28.269
Total sale growth (%): 2005–2007	382.89	620.4
Employee growth (%): 2005–2007	99.04	102.87
Labour productivity 2007	392,486	285,803
Labour productivity growth (%): 2005–2007	200.08	439.59
Duration in SP	2.72	1.948
Absorptive capacity	3.74	0.67596
Innovative performance indicators		
Patents	0.36	1.254
Developed not introduced	1.52	2.502
Sales of improved innovations (%)	44.6	36.053
Sales of new innovations (%)	35.4	33.320
Sales of new/improved-to-market innovations (%)	45.94	34.265
Other results of innovations	3.7667	0.75615

do not. This enables us to answer the third research question: what are the differences between these groups? To answer this question, group comparison on various dimensions is needed. In this research, independent *T*-tests are used to compare the relational characteristics of knowledge exchange of these two groups. Group 0 denotes the on-park firms without on-park networks and therefore they only interact with off-park firms; while Group 1 represents those who have both on-park ties and off-park ties. Since there are no relations with on-park firms in Group 0, the relational characteristics of the knowledge exchange are with the off-park only. Although Group 0 does not interact formally or informally with other on-park firms, this group of firms is still able to receive unintended knowledge that is flowing to the Hub. Therefore, the flows for unintended knowledge have two forms: on-park and off-park.

4.3.2. *Comparing tie characteristics*

The results of the *T*-test are summarised in Table 5. Some interesting observations can be made. One would expect that on-park firms who do not interact with other on-park firm (Group 0) will put more effort in establishing interactions with off-park firms. However, the result shows that Group 0 firms have less direct formal, informal and social ties with off-park firms as compared to Group 1 firms. The difference between the two groups as to informal direct ties is statistically significant at the *p*-level of 0.05.

Moreover, Group 0 firms have both higher inter-organisational and interpersonal trust with the off-park firms, although the differences are not statistically significant. For Group 0 we find that the technological knowledge from the off-park public knowledge sources (universities, research laboratories, innovation centres and sector institutions) is more related and useful, and the firms interact more frequently with these sources. On the other hand, Group 1 firms interact more often with private knowledge sources (competitors, buyers, suppliers and consultants) and find the knowledge from these sources more useful at a significant level.

One also would expect Group 0 to interact with a more diverse set of knowledge sources. However, the level of diversity of actors that Group 0 interacts with is lower. In other words, Group 0 interacts with fewer categories of knowledge sources. Furthermore, Group 0 has close organisational proximity on the internal aspects (organisational structure, routines and values) but not on the external aspects (sharing similar third partners). Lastly, Group 1 gets more unintended knowledge flows from the on-park firms as compared with Group 0.

4.3.3. *Comparing actor characteristics*

Besides the relational characteristics, the firms' characteristics between Group 0 and Group 1 are also analysed. The results of independent *T*-tests are shown in Table 6.

Although there are no significant differences between Group 0 and Group 1 in terms of their firm characteristics, one can still notice some interesting findings. Firms in Group 0 are slightly late comers on the Hub than those in Group 1, but Group 0 firms have almost double the numbers of total employees than Group 1 firms. Between 2005 and 2007, Group 0 has higher relative growth of total sales whereas Group 1 grows relatively stronger on employees. What really is surpising in Table 6 is that there are no statistically significant differences between the two groups as far as innovative sales and patents filed are concerned. One would expect that firms more strongly embedded in knowledge exchange networks (Group 1 firms) would outperform firms without such strong embeddedness (Group 0 firms). Moreover, the fact that on-park firms have knowledge exchange relations with other on-park firms does not seem to have added value to them as far as innovative outcomes are concerned. These findings give us reason to believe that there

Table 5. Results of independent T-tests of relational characteristics of Group 0 and 1 firms.

Variables (knowledge exchange with off-park firms)		Group 0: On-park firms with no on-park knowledge exchange relations, only with off park firms ($N = 11$)		Group1: On-park firms with on-park and off-park knowledge exchange relations ($N = 14$)		p-value[b] T-test[a]
		Mean	SD	Mean	SD	
Direct ties	Number of formal ties	7.82	11.453	28.36	51.79	−20.539
	Number of informal ties	6.55	9.933	16.43	10.515	−9.883*
	Number of social ties	24.55	48.757	123.29	349.174	−98.740
Trust	Inter-organisational trust	5.068	0.916	4.7946	1.363	0.274
	Interpersonal trust	4.709	1.122	4.2	1.169	0.509
Geographical proximity	Location of actors who provide supplementary knowledge	0.091	1.185	−0.714	0.868	0.162
	Location of actors who provide core knowledge	−0.315	0.816	0.248	1.088	−0.563
Technological proximity	Technological proximity of public knowledge sources	0.566	1.185	−0.045	0.872	0.101
	Technological proximity of private knowledge sources	−0.162	1.115	0.127	0.922	−0.29
Organisational proximity	Internal organisational proximity	0.284	1.068	−0.223	0.92	0.507
	External organisational proximity	−0.008	1.206	0.006	0.853	−0.014
Frequency	Frequency score for public knowledge sources	2.564	1.422	−0.201	0.438	0.458
	Frequency score for private knowledge sources	−0.162	1.09	0.127	0.945	−0.29
Usefulness of knowledge	Usefulness score from public knowledge sources	0.948	1.327	−0.075	0.691	0.169
	Usefulness score from private knowledge sources	−0.453	0.877	0.356	0.972	−0.81*
Diversity		3.36	1.69	3.71	1.541	−0.351
Unintended knowledge flow off park		1.591	0.8	1.56	0.789	0.031
Unintended knowledge flow on park		0.472	0.222	0.833	0.429	−0.361*

[a]Mean differences between two groups.

[b]Significance at the 5% level (p-value <0.05).

*Denotes mean difference is statistically significant at $p < 0.05$.

Table 6. Results of independent *T*-tests of firm characteristics.

	Group 0		Group1		
	On-park firms with no on-park knowledge exchange relations, only with off park firms ($N = 11$)		On-park firms with on-park and off-park knowledge exchange relations ($N = 14$)		T-test[a]
Variables	Mean	SD	Mean	SD	p-value[b]
Firm age	5.27	3.894	5.29	3.911	−0.013
Firm size	24	41.96	9.07	3.931	14.929
Total sale growth (%)	558.43	883.84	265.87	361.05	292.57
Employee growth (%)	85.07	110.37	109.78	99.89	−24.71
Labour productivity 2007	365,691	312,577	409,711	278,012	−44,019
Labour productivity growth (%)	433.39	732.51	83.42	129.46	349.96
Years in SP	2.45	1.036	2.93	2.464	−0.474
Absorptive capacity	3.739	0.526	3.741	0.794	−0.002
Firm's innovative performance					
Patents	0.55	1.809	0.21	0.579	0.331
Developed not introduced	1.09	1.30	1.86	3.159	−0.766
Sales of improved innovations (%)	43.18	37.435	45.71	36.314	−2.532
Sales of new innovations (%)	35.91	38.524	35	30.128	0.909
Sales of total innovations (%)	79.09	35.342	80.71	25.484	−1.623
Sales of new/improved-to-market innovations (%)	33.18	41.126	26.43	31.097	6.753
Other results of innovations	3.561	0.814	3.929	0.694	−0.302

[a]Mean differences between two groups.
[b]Significance at the 5% level (p-value <0.05).

are some indications that the Innovation Hub does not give the knowledge exchange environment (yet) as many have hoped for.

5. Conclusions and discussion

Policy makers often regard science parks as important drivers of regional economic development because they provide firms with a facilitating environment in which they can more easily set-up and maintain knowledge intensive inter-organisational relationships. The knowledge flows among various actors are supposed to play an important role in science parks and the purpose of the paper is to examine knowledge exchange behaviour of on-park firms in order to answer three main research questions:

(1) What are the knowledge exchange behaviours of on-park firms?
(2) Do these behaviours distinguish groups among on-park firms?
(3) If so, what are the differences between these groups?

In this section, the most important findings of this study are summarised and discussed. After carefully describing the theoretical and methodological background of the study, the empirical

analyses consisted of two parts. In the first part, the focus was on the knowledge exchange behaviour of on-park firms and the characteristics of their knowledge exchange relationships. It was found that compared with on-park knowledge exchange relationships:

- The knowledge exchange relationships with off-park firms occur more frequently. This is especially true for social ties;
- The knowledge exchange relationships with off-park firms are more technologically related;
- The knowledge exchange relationships with off-park firms are more organisationally close;
- The knowledge exchange interactions with off-park firms are more frequent;
- The knowledge exchange relationships with off-park firms are assessed as generating more useful knowledge;
- The off-park actors involved are of a more diverse nature;
- More unintended knowledge flows take place in exchange relationships with off-park firms.

An interesting finding is the importance of off-park social ties as relevant sources for on-park firms. This has been observed more often in the literature, especially for young, new and high-tech organisations (Maurer and Ebers 2006). Using their social capital is a way to deal with the 'liability of newness' (Freeman, Carroll, and Hannan 1983), that is, that new and young firms experience a higher probability of failure owing to a lack of external resources, access to formal financial funding and internal routines. By capitalising on their social network ties, which provide informal funding and advice, this liability is mitigated.

Our finding that on-park firms interact more often with off-park than with on-park firms is as such not a surprise. After all, the number of off-park firms with which knowledge exchange relationships can be established is much higher than the number of on-park firms. However, our results indicate that the quality and effectiveness of knowledge exchange relationships with off-park firms seems to be far better than those with on-park firms. A negative interpretation of these findings is that the Innovation Hub does not perform its functions well. However, this might be a too harsh an interpretation. Research has shown that most knowledge exchange relationships are reciprocal (Chiu, Hsu and Wang 2006; Watson and Hewett 2006). If we assume the same is true for the off-park relationships, than the off-park firms profit from the knowledge developed by the on-park firms. In this sense, the Hub could be regarded as focal driver of technological development.

The second part of our analyses answered research questions two and three. We were able to show that two groups of on-park firms exist. A group of on-park firms that has only knowledge exchange relationships with off-park firms (Group 0) and a group of on-park firms with both on and off-park relationships (Group 1). More specifically, we found that:

- Group 1 firms have more (informal) direct ties;
- Group1 firms get more useful knowledge from private knowledge sources;
- Group 1 firms have a higher inflow of unintended knowledge from other on-park firms;
- That there are no differences between the two groups as far as firm characteristics are concerned.

How can we interpret these results? One interpretation could be that the technologies of Group 0 firms are at an earlier stage of the technology life cycle as the technologies of Group 1 firms. The data give some indications that Group 0 firms are in the early stages of this cycle, because they especially interact with organisations part of the public knowledge infrastructure (universities, research labs) to which they feel organisationally and technologically close. Moreover, they assess

the knowledge acquired from these sources more useful and the firms in this group generate twice as much patents as firms in the other group. All of this could imply that Group 0 firms are primarily technology developers that use the more fundamental knowledge generated by actors in the public knowledge infrastructure that cannot be found on-park. Group 1 firms, however, interact more with organisations part of the private knowledge infrastructure (buyers, suppliers) to whom they feel more organisationally and technologically related. For the South African situation, Oerlemans and Pretorius (2006) have shown that the knowledge acquired from buyers and suppliers often is used for incremental innovation of already existing products and services. This would imply that Group 1 firms are closer to or are already commercialising their innovations.

A different interpretation could be that a science park such as the Innovation Hub serves other purposes of on-park firms in Group 0. Location on a science park is not primarily for networking and knowledge exchange but for reputation-building and creating an innovative firm image, which might give these firms an advantage in the market. A striking finding is that there are no differences between the two groups concerning their innovative outcomes, despite the fact that Group 1 firms have a more extended knowledge transfer network. The literature gives ample evidence that higher levels of network embeddedness are beneficial to the innovation outcomes of organisations (Ahuja 2000). However, the firms in Group 1 seem unable to reap the benefits of their more extended network, which might be due to fact that their absorptive capacity is insufficiently high. Having more knowledge transfer ties with external actors implies that more knowledge and information has to be processed by the focal firm, which asks for higher levels of absorptive capacity. In the light of our finding that there are no differences between the absorptive capacity levels of the two groups, it indeed might be the case that this ability is not high enough for the Group 1 firms.

Even though our findings provide valuable insights, our study has limitations. Our sample covers a large part (52%) of the firms located on this science park. Nevertheless, given a number of specifics of the South African economy (e.g. high unemployment, high crime rates, high dependency on foreign technology) and the relatively small sample, it is difficult to make general claims. In other words, the external validity of our findings is not high and thus only applicable to the Innovation Hub situation.

As far as future research directions are concerned, we suggest that researching knowledge inflows and outflows of science park-based firms could provide additional insights. In this research only the inflows are explored, but by adding the knowledge outflows, a more complete picture of the (regional) impact of a science park could emerge. Furthermore, this research model can be extended by using a matched sampling approach in which on-park firms and comparable off-park firms are included. This allows for a comparison of the performance of on-park firms while controlling for the performance of off-park firms. Consequently, a truer picture of the performance of on-park firms will emerge. In future research, our approach also can be used for benchmarking the knowledge exchange behaviours of firms located on science parks in emerging and developed economies. Such a comparison will increase the insights in the differences between the functioning of science parks in these regions and help to identify innovation bottlenecks.

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